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(54) Title: POLYCLONAL-POLYCLONAL ELISA ASSAY FOR DETECTING N-TERMINUS-PROBNP

(57) Abstract: A specific and sensitive in vitro ELISA assay and diagnostic test kit is disclosed for determining levels of NT-proBNP protein in a variety of bodily fluids, non-limiting examples of which are blood, serum, plasma, urine and the like. The NT-proBNP ELISA assay test employs the sandwich ELISA technique to measure circulating NT-proBNP in human plasma. In order to obtain antibodies with specific binding properties for targeted amino acid sequences within human proBNP, recombinant human proBNP (or rhproBNP) was expressed and purified for use as an immunogen. Polyclonal antibodies (PAb) to specific amino acid sequences were subsequently purified from goat serum by sequential affinity purification. Recombinant human NT-proBNP (or rhNT-proBNP) was expressed and purified in order to obtain material for use in calibration of a quantitative method for measurement of human NT-proBNP.

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POLYCLONAL-POLYCLONAL ELISA ASSAY FOR DETECTING N-TERMINUS-proBNP

FIELD OF THE INVENTION

This invention relates to an NT-proBNP protein ELISA assay procedure and test kit which is a specific and sensitive *in vitro* assay for measuring the concentration of NT-proBNP in bodily fluids, particularly human plasma. The invention particularly relates to an NT-proBNP protein ELISA assay having a particularly high diagnostic specificity, whereby the assay is particularly designed to be predictive of mortality as a result of congestive heart failure.

BACKGROUND OF THE INVENTION

B-type natriuretic peptide (Brain natriuretic peptide, BNP) belongs to the family of structurally similar, but genetically distinct natriuretic peptides (NPs) first described by de Bold *et al.*(de Bold AJ. Heart atria granularity: effects of changes in water-electrolyte balance. Proc Soc Exp Biol Med 1979; 161:508-511; de Bold AJ, Borenstein HB, Veress AT and Sonnenberg H. A rapid and potent natriuretic response to intravenous injection of atrial myocardial extracts in rats. Life Sci 1981; 28:89-94).

The NPs possess potent diuretic, natriuretic and vasodilatory properties and have been reported as valuable diagnostic and prognostic markers in cardiovascular disease, particularly for patients in New York Heart Association (NYHA) classes I-IV congestive heart failure (CHF) (Boomsma F and van den Meiracker AH. Plasma A- and B-type natriuretic peptides: physiology, methodology and clinical use. Cardiovasc Res 2001; 51:442-449).

The *BNP* gene encodes for a 108 amino acid residue precursor molecule, proBNP (Sequence ID No. 1). Prior to secretion by cardiomyocytes, cleavage of this prohormone results in the generation of bioactive BNP from the COOH terminus. In 1995, Hunt *et al.* (Hunt PJ, Yandle TG, Nicholls MG, Richards AM and Espiner EA. The Aminoterminal Portion Of Probrain Natriuretic Peptide (Probnp) Circulates In Human Plasma. Biochem Biophys Res Commun 1995; 14:1175-1183; Hunt PJ, Richards AM, Nicholls MG, Yandle TG, Doughty RN and Espiner EA. Immunoreactive Amino-Terminal Pro-Brain Natriuretic Peptide (NT-PROBNP): A New Marker Of Cardiac Impairment. Clin Endocrinol 1997; 47:287-296) demonstrated that fragments corresponding to the N-terminal portion of the cleaved prohormone, NT-proBNP, also circulated in

plasma, and like BNP, were a potentially important, and possibly more discerning, marker of ventricular dysfunction.

Many studies have demonstrated the clinical utility of measuring plasma concentrations of NPs, including NT-proBNP. NPs have been suggested as the biomarkers of choice for diagnosis and risk stratification of patients with heart failure (Clerico A, Del Ry S and Giannessi D. Measurement Of Cardiac Natriuretic Hormones (Atrial Natriuretic Peptide, Brain Natriuretic Peptide, And Related Peptides) In Clinical Practice: The Need For A New Generation Of Immunoassay Methods. Clin Chem 2000; 46:1529-1534: Mair J, Hammerer-Lercher A and Puschendorf B. The Impact Of Cardiac Natriuretic Peptide Determination On The Diagnosis And Management Of Heart Failure. Clin Chem Lab Med 2001; 39:571-588; Sagnella GA. Measurement And Importance Of Plasma Brian Natriuretic Peptide And Related Peptides. Ann Clin Biochem 2001; 38:83-93; Selvais PL, Donckier JE, Robert A, Laloux O, van Linden F, Ahn S, Ketelslegers JM and Rousseau MF. Cardiac Natriuretic Peptides For Diagnosis And Risk Stratification In Heart Failure: Influences Of Left Ventricular Dysfunction And Coronary Artery Disease On Cardiac Hormonal Activation. Eur J Clin Invest 1998;

28:636-642; McDonagh TA, Cunningham AD, Morrison CE, McMurray JJ, Ford I, Morton JJ and Dargie HJ. Left Ventricular Dysfunction, Natriuretic Peptides, And Mortality In Urban Population. Heart 2001; 86:21-26). Several studies have shown the utility of using NP measurements to identify patients with left ventricular dysfunction, even amongst patients who are asymptomatic (*i.e.* NYHA class I) and it has been suggested that NP measurements as a screening tool may help effectively target patients within high risk heart failure groups (*e.g.* coronary artery disease, hypertension, diabetes, aged) who will require follow-up assessment and treatment (Hughes D, Talwar S, Squire IB, Davies JE and Ng LL. An Immunoluminometric Assay For N-Terminal Pro-Brain Natriuretic Peptide: Development Of A Test For Left Ventricular Dysfunction. Clin Sci 1999; 96:373-80; Omland T, Aakvaag A, Vik-Mo H. Plasma Cardiac Natriuretic Peptide Determination As A Screening Test For The Detection Of Patients With Mild Left Ventricular Impairment. Heart 1996; 76:232-237; McDonagh TA, Robb SD, Murdoch DR, Morton JJ, Ford I, Morrison CE, *et al.* Biochemical Detection Of Left-Ventricular Systolic Dysfunction. Lancet 1998; 351:9-13; Schulz H, Langvik TA, Lund Sagen E, Smith J, Ahmadi N and Hall C.

Radioimmunoassay For N-Terminal Probrain Natriuretic Peptide In Human Plasma. Scand J Clin Lab Invest 2001; 61:33-42; Talwar S, Squire IB, Davies JE, Barnett DB and Ng LL. Plasma N-Terminal Pro-Brain Natriuretic Peptide And The ECG In The Assessment Of Left-Ventricular Systolic Dysfunction In A High Risk Population. Eur Heart J 1999; 20:1736-1744; Hystad ME, Geiran OR, Attramadal H, Spurkland A, Vege A, Simonsen S and Hall C. Regional Cardiac Expression And Concentration Of Natriuretic Peptides In Patients With Severe Chronic Heart Failure. Acta Physiol Scand 2001; 171:395-403; Hobbs FDR, Davis RC, Roalfe AK, Hare R, Davies MK and Kenkre JE. Reliability Of N-Terminal Pro-Brain Natriuretic Peptide Assay In Diagnosis Of Heart Failure: Cohort Study In Representative And High Risk Community Populations. BMJ 2002; 324:1498).

NPs have been shown to have good prognostic value with regards to both morbidity and mortality in heart failure. Several studies have also demonstrated the utility of NP measurements in the prediction of left ventricular dysfunction and survival following acute myocardial infarction (Richards AM, Nicholls MG, Yandle TG, Frampton C, Espiner EA, Turner JG, *et al*. Plasma N-Terminal Pro-Brain Natriuretic Peptide And

Adrenomedullin. New Neurohormonal Predictors Of Left Ventricular Function And Prognosis After Myocardial Infarction. Circulation 1998; 97:1921-1929; Luchner A, Hengstenberg C, Lowel H, Trawinski J, Baumann M, Riegger GAJ, *et al*. N-Terminal Pro-Brain Natriuretic Peptide After Myocardial Infarction. A Marker Of Cardio-Renal Function. Hypertension 2002; 39:99-104; Campbell DJ, Munir V, Hennessy OF and Dent AW. Plasma Amino-Terminal Pro-Brain Natriuretic Peptide Levels In Subjects Presenting To The Emergency Department With Suspected Acute Coronary Syndrome: Possible Role In Selecting Patients For Follow Up? Intern Med J 2001; 31:211-219; Nilsson JC, Groenning BA, Nielsen G, Fritz-Hansen T, Trawinski J, Hildebrandt PR, *et al*. Left Ventricular Remodeling In The First Year After Acute Myocardial Infarction And The Predictive Value Of N-Terminal Pro Brain Natriuretic Peptide. Am Heart J 2002; 143:696-702). Monitoring NP levels may also provide guidance in tailoring therapies to meet the required intensity of the individual patient and in monitoring therapeutic efficacy (Richards AM, Doughty R, Nicholls G, MacMahon S, Sharpe N, Murphy J, *et al*. Plasma N-Terminal Pro-Brain Natriuretic Peptide And Adrenomedullin. Prognostic Utility And Prediction Of Benefit From

Carvedilol In Chronic Ischemic Left Ventricular Dysfunction. J Am Coll Cardiol 2001; 37:1781-1787; Troughton RW, Frampton CM, Yandle TG, Espiner EA, Nicholls MG and Richards AM. Treatment Of Heart Failure Guided By Plasma Aminoterminal Brain Natriuretic Peptide (N-BNP) Concentrations. Lancet 2000; 355:1126-30).

PRIOR ART

WO 93/24531 (US 5,786,163) to Hall describes an immunological method of identifying N-terminal proBNP and the antibodies used for it. To obtain these antibodies single synthetically produced peptides from the sequence of N-terminal proBNP are used. The production of antibodies by means of peptide immunization is possible in principle but the affinity regarding the whole molecule generally is too low to reach the necessary sensitivity in a test procedure. In addition, there is a danger that when using peptides the antibodies obtained can for example identify the C-terminus of the peptide and can therefore only bind to this fragment of the whole molecule, thus resulting in antibodies which generally cannot bind to the whole molecule, or can do so to only a limited extent. In WO 93/24531 an antibody against one single peptide derived

from the N-terminal proBNP is produced. It is shown that the antibodies produced bind to the immunization peptide (amino acids 47-64) in the competitive test format. It is however not shown that the antibodies are able to bind to native N-terminal proBNP as a whole molecule in a sample. Additionally, the sandwich test described in WO 93/24531 in a sample cannot be performed as described since there was no appropriate standard material and no antibodies against two different epitopes.

Additionally, the competitive test performed in PCT 93/24531, where the peptide 47-64 competes in a labelled form as a tracer with a sample or the unlabelled peptide standard 47-64 to bind to polyclonal antibodies from rabbit serum, suffers from the fact that only a very moderate competition is reached after 48 hours of incubation from which only a low detection limit of approx. 250 fmol/ml can be derived. This is neither sufficient for the differentiation of healthy individuals and patients suffering from heart failure nor for a differentiated classification of patient samples into the severity degrees of heart failure. In addition, the long incubation times of the competitive test are not acceptable for routine measurements of the samples in automated laboratories.

Hunt et al. (Clinical Endocrinology 47 (1997),287-296) also describes a competitive test for the detection of N-terminal proBNP. For this a complex extraction of the plasma sample is necessary before the measurement; this may lead to the destruction of the analyte and error measurements. The antiserum used is produced analogously to WO 93/24531 by immunization with a synthetic peptide- Hunt et al. produces the antiserum by immunization with the N-terminal proBNP amino acids 1-13 and the peptide of amino acids 1-21 is used as a standard. For this test long incubation times are necessary too. After an incubation of 24 hours a lower detection limit of 1.3 fmol/ml is reached.

WO 00/45176, Method of Identifying N-Terminal proBNP, Karl et al., discloses monoclonal and polyclonal antibodies isolated via the use of a recombinant NT-proBNP immunogen. The reference suggests the formation of an assay using the disclosed antibodies as being specific for NT-proBNP in bodily fluids. As will be more fully described, a comparison of the area under the curve (AUC)of a plot of the Receiver Operated Characteristics (ROC) for this assay versus the assay of the instant invention indicates that the instant invention demonstrates superior diagnostic performance.

WO 00/35951, Natriuretic Peptide Fragments, is directed toward an assay for NT-proBNP utilizing two antibodies directed toward differing epitopes of the NT-proBNP sequence. This assay suffers from similar deficiencies as that of Hall (5,786,163) in that the antibodies are raised against synthetic peptide fragments as the immunogen.

SUMMARY OF THE INVENTION

The instantly disclosed NT-proBNP protein ELISA assay and test kit is a specific and sensitive *in vitro* assay that is capable of measuring the concentration of NT-proBNP in a variety of bodily fluids, non-limiting examples of which are blood, serum, plasma, urine and the like. The following examples and descriptions will exemplify the use of the assay in human plasma.

As used herein, the term "antibody or antibodies" includes polyclonal and monoclonal antibodies of any isotype (IgA, IgG, IgE, IgD, IgM), or an antigen-binding portion thereof, including but not limited to F(ab) and Fv fragments, single chain antibodies, chimeric antibodies, humanized antibodies, and a Fab expression library.

The Nt-proBNP test employs the sandwich ELISA technique to measure circulating Nt-proBNP in human plasma. Microplate wells coated with goat polyclonal anti-Nt-proBNP capture protein constitute the solid phase. Test subject plasma, standards and controls are added to the coated wells and incubated with incubation buffer. No sample extraction step is required. If Nt-proBNP protein is present in the test sample, it will be captured by Nt-proBNP specific antibody coated on the wells. After incubation and washing, a biotinylated goat polyclonal anti-Nt-proBNP detector antibody is added to the wells. The detector antibody binds to the Nt-proBNP protein bound to anti-Nt-proBNP capture antibody, thus forming a sandwich. After incubation and washing, a horseradish peroxidase (HRP)-streptavidin conjugate solution is added to the wells. Following incubation and washing, an enzyme substrate is added to the wells and incubated. An acidic solution is then added in order to stop the enzymatic reaction. The degree of enzymatic activity of immobilized HRP is determined by measuring the optical density of the oxidized enzymatic product in the wells at 450nm. The absorbance at 450nm is proportional to the amount of Nt-proBNP in the test subject sample. A set of Nt-proBNP

protein standards is used to generate a standard curve of absorbance versus Nt-proBNP concentration from which the Nt-proBNP concentrations in test specimens and controls can be calculated.

Accordingly, it is an objective of the instant invention to provide goat polyclonal antibodies raised against recombinant human proBNP, which antibodies are specifically selected to exhibit a specific affinity for targeted amino acid sequences within human proBNP.

It is a further objective of the instant invention to provide a quantitative method for measurement of human NT-proBNP, whereby a diagnostic/screening tool for accurately predicting mortality in congestive heart failure patients may be determined.

It is still an additional objective of the instant invention to provide an ELISA Test Kit for the purpose of carrying out the above-outlined diagnostic/screening procedure to determine levels of NT-proBNP.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 illustrates the method of selection of NT-proBNP and target peptides starting from a pre-proBNP precursor protein;

Figure 2 is an ROC curve for the goat polyclonal/polyclonal assay;

Figure 3 is a box-plot of NT-proBNP levels in NYHA Class III and IV versus controls;

Figure 4 is a box-plot of NT-proBNP levels in control subjects, stratified by age;

Figure 5 outlines the ELISA procedure for utilizing the goat polyclonal/polyclonal assay of the instant invention.

DETAILED DESCRIPTION OF THE INVENTION

The Nt-proBNP test employs the sandwich ELISA technique to measure circulating Nt-proBNP in human plasma. Microplate wells coated with goat polyclonal anti-Nt-proBNP capture protein constitute the solid phase. Test subject plasma, standards and controls are added to the coated wells and incubated with incubation buffer. No sample extraction step is required. If Nt-proBNP protein is present in the test sample, it will be captured by Nt-proBNP specific antibody coated on the wells. After incubation and washing, a biotinylated goat polyclonal anti-Nt-proBNP detector antibody is added to the wells. The detector antibody binds to the Nt-proBNP, or immunogenic fragments thereof, e.g.

polypeptide fragments which are recognized by said antibody, which are in turn bound to anti-NT-proBNP capture antibody, thus forming a sandwich. After incubation and washing, a horseradish peroxidase (HRP)-streptavidin conjugate solution is added to the wells. Following incubation and washing, an enzyme substrate is added to the wells and incubated. An acidic solution is then added in order to stop the enzymatic reaction. The degree of enzymatic activity of immobilized HRP is determined by measuring the optical density of the oxidized enzymatic product in the wells at 450nm. The absorbance at 450nm is proportional to the amount of Nt-proBNP in the test subject sample. A set of Nt-proBNP protein standards is used to generate a standard curve of absorbance versus Nt-proBNP concentration from which the Nt-proBNP concentrations in test specimens and controls can be calculated. It is understood that detection of the immunoreaction may be accomplished via direct or indirect methods which are well-known in the art.

In order to obtain antibodies with specific binding properties for targeted amino acid sequences within human proBNP, recombinant human proBNP (or rhproBNP) was expressed and purified for use as an immunogen. ProBNP-

pUC9 plasmid construct was obtained from Dr. Adolfo J. de Bold (Ottawa Heart Institute). The full-length rhproBNP open reading frame (ORF) was obtained by polymerase chain reaction (PCR) and subcloning into pET32c (NcoI/XhoI). The pET32c vector was modified by removing 81 nucleotides so that the final fusion protein would not contain the S-tag and enterokinase sites. The sequence at the N-terminus of the rhproBNP ORF consisted of thioredoxin and poly-histidine tags and a thrombin cleavage site. There was no extra sequence at the C-terminus. The protein was expressed in *Escherichia coli* BL21 (DE3) cells and the crude cellular extract was prepared in non-denaturing conditions. The subsequent affinity purification was completed by Ni-NTA chromatography following the supplier's recommendations. Prior to injections, endotoxin levels in the rhproBNP solutions were lowered to acceptable levels using a Detoxigel® endotoxin-removing resin following the supplier's recommendations.

Polyclonal Antibody Production and Purification:

Figure 1 shows four constructs (top to bottom of page): Pre-proBNP (precursor) a.a. #1-134; proBNP a.a. #27-134 (=proBNP a.a. #1-108); NT-proBNP (a.a. #1-76) + BNP-32 (a.a. #77-108) and proBNP (a.a. #1-108). The

fourth construct (bottom of page) shows three peptides: peptide 1 =proBNP a.a. #1-25; peptide 2 =proBNP a.a. #26-51 and peptide 3=proBNP a.a. #52-76. It is noted that goat polyclonal antibody affinity purified against amino acid peptide 2 (a.a.26-51) was selected for use as capture. Goat polyclonal affinity purified against amino acid peptide 1 (a.a. 1-25) was selected for use as detector. Goat polyclonal antibody was also affinity purified against amino acid peptide 3 (a.a. 52-76), however this material was not selected for use in the final NT-proBNP ELISA format.

Goats (La Mancha or Toggenburg breed) were immunized with purified recombinant human full-length proBNP (rhproBNP). A primary intramuscular injection at multiple sites of 500ug purified rhproBNP emulsified in Complete Freund's Adjuvant was administered, followed by bi-weekly 250ug intramuscular injections at multiple sites of the purified rhproBNP emulsified in Freund's incomplete adjuvant. The titer of immunized goats was monitored routinely by screening serum using a half-sandwich ELISA technique.

Polyclonal antibodies (PAb) specific for amino acid sequences within proBNP (1-25, 26-51, 52-76 or 77-108) of Sequence ID No. 1 were subsequently purified from

goat serum by sequential affinity purification using cyanogen bromide activated sepharose-4B (Pharmacia) coupled, according to the supplier's recommendations, to the following proteins or peptide sequences:

1. human IgG (Jackson ImmunoResearch)
2. mouse IgG (Jackson ImmunoResearch)
3. proBNP amino acid sequence #1-25 of Sequence ID No. 1 (H P L G S P G S A S D L E T S G L Q E Q R N H L Q) coupled to Keyhole Limpet Haemocyanin (ADI Inc.)

OR

3. proBNP amino acid sequence #26-51 of Sequence ID No. 1 (G K L S E L Q V E Q T S L E P L Q E S P R P T G V W) coupled to Keyhole Limpet Haemocyanin (ADI Inc.)

OR

3. proBNP amino acid sequence #52-76 of Sequence ID No. 1 (K S R E V A T E G I R G H R K M V L Y T L R A P R) coupled to Keyhole Limpet Haemocyanin (ADI Inc.)

OR

3. proBNP amino acid sequence #77-108 of Sequence ID No. 1 (BNP-32, S P K M V Q G S G C F G R K M D R I S S S S G L G C K V L R R H) coupled to Keyhole Limpet Haemocyanin (ADI Inc.)

The purified polyclonal antibodies were dialyzed against 20mM PBS, pH 7.4, concentrated by ultrafiltration and stored at -20°C.

Expression of Recombinant Human NT-proBNP

In order to obtain material for use in calibration of a quantitative method for measurement of human NT-proBNP, recombinant human NT-proBNP (or rhNT-proBNP) was expressed and purified. A proBNP-pUC9 plasmid construct was obtained from Dr. Adolfo J. de Bold (Ottawa Heart Institute). The rhNT-proBNP ORF was obtained by PCR and subcloning into pET32c (NcoI/XhoI). The sequence at the N-terminus of the rhNT-proBNP ORF consisted of thioredoxin, poly-histidine, and S-tag tags, as well as thrombin and enterokinase cleavage sites. There was no extra sequence at the C-terminus. The protein was expressed in *Escherichia coli* BL21 (DE3) cells and the crude cellular extract was prepared in non-denaturing conditions. The subsequent affinity purification was

completed by Ni-NTA chromatography following the supplier's recommendations.

Optimal ELISA specificity and sensitivity for recombinant human proBNP and recombinant human NT-proBNP were obtained using the combination of goat polyclonal antibody affinity purified against proBNP amino acid peptide sequence 26-51 as capture with goat polyclonal antibody affinity purified against proBNP amino acid peptide sequence 1-25 as detector. Now referring to Figure 5, the procedure for carrying out the ELISA assay of the instant invention is set forth.

A summary for the procedure as shown in Figure 5 is as follows: Add 50uL incubation buffer + 50uL sample/calibrator; Incubate 2h at room temperature; add 100uL detector solution; incubate 1h at room temperature; add 100uL reporter solution; incubate 30 minutes at room temperature; add 100uL TMB solution; incubate 10 minutes at room temperature in the dark; stop reaction with 100uL 1N H_2SO_4; read OD_{450nm}.

Subsequent analysis of the data derived from human plasma samples tested in accordance with these procedures have demonstrated the utility of this antibody combination for yielding excellent sensitivity and specificity when measuring NT-proBNP levels in

apparently healthy individuals versus heart failure patients.

In accordance with this invention, an ELISA Test Kit is provided for the purpose of carrying out the above-outlined procedure.

Reagents Supplied:

Anti-Nt-proBNP Protein Coated Microtitration Strips

One stripholder containing 96 microtitration wells coated with goat polyclonal anti-Nt-proBNP antibody. Store at 2-8°C, in the pouch with desiccant, until expiry.

Nt-proBNP Protein Standards

Six vials, each containing one of the following standards: 0, 50, 150, 375, 1500, and 3000 pg/ml of Nt-proBNP, are provided. Each vial contains 0.5ml, except for the 0 pg/ml standard which contains 1.0 ml. The extra volume allows for diluting samples that have values greater than 3000 pg/ml, if retesting is desired. Store at -70±10°C. Kept at this temperature, the standards are stable for at least 3 cycles of freeze/thaw and up to 6 months.

Nt-proBNP Protein Controls

Two vials, 0.5 ml each, containing Nt-proBNP controls at low and high protein concentration. Store at -70±10°C. Kept at this temperature, the controls are stable for at least 3 cycles of freeze/thaw and up to 6 months.

Incubation Buffer

One vial containing 10 ml of incubation buffer. Store at 2-8°C until expiry.

Detector Antibody

One vial containing 10 ml of biotinylated anti-Nt-proBNP goat polyclonal antibody. Store at 2-8°C until expiry.

Horseradish Peroxidase (HRP)-Streptavidin Conjugate

One vial containing 10 ml of streptavidin labeled with horseradish peroxidase. Store at 2-8°C until expiry.

Chromogen Solution

One vial containing 10 ml of 3, 3', 5, 5'-tetramethylbenzidine (TMB) substrate solution. Store at 2-8°C until expiry.

Wash Concentrate

One bottle containing 60 ml phosphate buffered saline with nonionic detergent. Dilute contents 25 fold with deionized water before use. Store at 2-8°C.

Stopping Solution

One bottle containing 10 ml 1N sulfuric acid. Store at 2-8°C.

Preparation of Reagents:

Wash Solution:

Pour the contents, 60 ml, of the concentrated wash solution into a clean container and add 1500 ml of distilled/de-ionized water to obtain 1560 ml of wash solution. The wash solution is stable for one month at room temperature provided that the bottle is kept tightly sealed and effort is made to avoid gross contamination of the contents.

Microplate Strips:

To avoid contamination, remove only the number of strips required for use. Reseal the remaining strips in the pouch with the desiccant provided. Placing the pouch in an airtight container with desiccant is recommended.

Assay Procedure:

The time between addition of samples, standards, and controls to the first well and the last well should not exceed 10 minutes. For large series of samples, run the ELISA in small batches to accommodate this time frame.

1. Mark the microplate wells to be used.

2. Add 50 µl of the incubation buffer to each well using a semi-automatic pipette.

3. Using a precision micropipette, add 50 µl of each test sample, Nt-proBNP standard, or Nt-proBNP control to the appropriate microwell. In order to ensure standard curve consistency, the following order of addition to the plate is recommended:

   a. Test samples

   b. Nt-proBNP standards

   c. Nt-proBNP controls

   It is recommended that Nt-proBNP standards and controls be assayed in duplicate.

4. Cover microwells using an adhesive plate cover and incubate for 2 hours on an orbital microplate shaker at room temperature.

5. Aspirate and wash each microwell three times with the wash solution using an appropriate microplate washer. Blot dry by inverting the plate on absorbent material.

   Since incomplete washing adversely affects assay precision, the use of an automatic microplate washer is highly recommended. Alternatively, if an automatic microplate washer is not available, washing

can be accomplished manually by repeatedly aspirating microwell contents and refilling each microwell with 340 μl of wash solution, three times.

6. Add 100 μl of biotinylated Nt-proBNP antibody to each well using a semi-automatic pipette.
7. Incubate the wells for 1 hour on an orbital microplate shaker at room temperature.
8. Aspirate and wash microwells three times with the wash solution using an appropriate microplate washer. Blot dry by inverting the plate on absorbent material.
9. Add 100 μl of HRP-streptavidin conjugate solution to each well using a semi-automatic pipette.
10. Cover microwells using an adhesive plate cover and incubate for 30 minutes on an orbital microplate shaker at room temperature.
11. Aspirate and wash microwells three times with wash solution. Blot dry by inverting the plate on absorbent material.
12. Add 100 μl of the TMB solution to each well using a semi-automatic pipette.
13. Incubate the wells in the dark for 10 minutes at room temperature. Avoid exposure to direct sunlight.

14. Add 100 μl of stopping solution (1N sulfuric acid) to each well using a semi-automatic pipette.

15. Measure the absorbance of the solution in the microwells using a microplate reader at 450 nm.

Calculation of Results:

- Calculate the mean absorbance for each well containing standard, control or test subject plasma.
- Plot the mean absorbance reading for each of the standards along the y-axis (quadratic) versus the Nt-proBNP concentration, in pg/ml, along the x-axis (linear).
- Draw the best fitting standard curve through the mean of the duplicate points.
- Determine the Nt-proBNP concentrations of the test subjects' plasma and controls by interpolating from the standard curve.
- Subject plasma specimens reading lower than the lowest standard should be reported as such.

Alternatively, a computer program may be used for handling ELISA type data to evaluate the Nt-proBNP concentrations in test subjects' plasma and controls.

The following data represent an example dose response curve using this assay:

Standard Dose (pg/ml)	Mean OD 450nm
0	0.069
50	0.105
150	0.173
375	0.323
1500	0.997
3000	1.796

Note: These values should not be used in lieu of a standard curve, which should be prepared at the time of assay.

Performance Characteristics

Quality Control:

Two controls - low and high - provided in this kit must be analyzed in each assay. It is recommended that each laboratory use additional controls for validation of each assay run.

Specificity

The following substances have been tested and shown to have no cross reactivity in the Nt-proBNP ELISA assay:

Protein	Concentration	Cross Reaction (%)
BNP-32	3 µg/ml	0
cTnI	3 µg/ml	0
cTnI/T/C Complex	3 µg/ml	0
CKMB	3 µg/ml	0

Accuracy / Recovery Study

Normal human plasma samples, containing undetectable endogenous Nt-proBNP protein levels, were spiked with Nt-proBNP to yield samples with final concentrations of approximately 1000, 450, and 90 pg/ml. Accuracy values for Nt-proBNP were between 81% and 106% (mean = 96.6%).

Table 1. Accuracy / Recovery

Sample	Endogenous Nt-proBNP pg/ml	Added Nt-proBNP pg/ml	Observed Nt-proBNP pg/ml	Accuracy (%)
1	0	1000	1030.032	103
	0	450	456.004	101
	0	90	87.624	97
2	0	1000	936.927	94
	0	450	433.574	96
	0	90	82.571	92
3	0	1000	990.567	99
	0	450	438.747	97
	0	90	72.469	81
4	0	1000	1003.113	100
	0	450	478.468	106
	0	90	94.365	105
5	0	1000	970.876	97
	0	450	407.735	91
	0	90	80.887	90

The accuracy of the Nt-proBNP assay was also evaluated by using 6 clinical samples with high endogenous Nt-proBNP. The samples were diluted 2-, 4-, 8-, 16-, 32-, and 64-fold and each dilution assayed in triplicate.

The accuracy was between 85% and 114% of the expected values.

Summary of NT-proBNP clinical data:

Data is available from 161 subjects diagnosed with congestive heart failure (NYHA Class III and Class IV) and 200 healthy normal control subjects. The receiver operating characteristic (ROC) curve is displayed in Figure 2; an area under the curve (AUC) of 0.991 was obtained, with a corresponding standard error (s.e.) of 0.0053. Figure 3 displays boxplots of proBNP levels in the control subjects and the heart failure subjects; at an optimal cutoff level of 96.7 pg/mL (representing the 97.5^{th} percentile of NT-proBNP levels with respect to the control subjects), the diagnostic sensitivity with respect to the heart failure subjects was 93.2% with 150 out of 161 such subjects with NT-proBNP levels above the cutoff.

A boxplot of NT-proBNP levels stratified by age category with respect to the healthy normal control subjects is displayed in Figure 4. There is a slight tendency towards a higher median NT-proBNP level with increasing age, but the differences among age categories are not significant in this respect (p= 0.073 when performing a nonparametric Kruskal-Wallis test).

Comparison with other NT-proBNP and BNP assays:

In the product insert for the Biosite Triage BNP test (*Triage© B-Type Natriuretic Peptide (BNP) Test*, Product insert, Biosite Diagnostics, Inc., 2001), a ROC curve analysis on clinical data obtained from 804 heart failure subjects and 1286 control subjects revealed an AUC of 0.955 (standard error = 0.0053). Comparing this AUC with that of the instantly disclosed NT-proBNP assay, following the procedure of Hanley and McNeil (Hanley JA and McNeil BJ (1982). "The meaning and use of the area under a receiver operating characteristic (ROC) curve." *Radiology* **143** 29-36), one finds that the instantly disclosed NT-proBNP assay has a significantly higher AUC ($p < 0.001$), indicative of superior diagnostic performance.

Fischer *et al.* (Fischer Y, Filzmaier K, Stiegler H, Graf J, Fuhs S, Franke A, Janssens U and Gressner AM (2001). "Evaluation of a New, Rapid Bedside Test for Quantitative Determination of B-Type Natriuretic Peptide." *Clinical Chemistry* **47** 591-594.) gave performance data comparing the Triage BNP test to an NT-proBNP EIA assay from Roche Diagnostics with respect to 93 subjects with underlying cardiac disease and suspected heart failure. In distinguishing subjects

with decreased ventricular function from those with preserved ventricular function, an AUC of 0.91 (± 0.033 s.e.) was obtained for the Triage BNP test, and an AUC of 0.86 (± 0.040 s.e.) was obtained for the Roche NT-proBNP assay. Given a reported correlation between the two neurohormone measurements of $r = 0.947$, and following the method of Hanley and McNeil (Hanley JA and McNeil BJ (1983), "A method of comparing the areas under Receiver Operating Characteristic curves derived from the same cases." *Radiology* **148** 839-843) for comparing AUC's derived from the same set of cases, one finds that the Triage BNP test has a significantly higher AUC than that of the Roche NT-proBNP assay ($p = 0.005$).

Hammerer-Lercher *et al.* (Hammerer-Lercher A, Neubauer E, Müller S, Pachinger O, Puschendorf B and Mair J (2001). "Head-to-head comparison of N-terminal pro-brain natriuretic peptide, brain natriuretic peptide and N-terminal pro-atrial natriuretic peptide in diagnosing left ventricular dysfunction." *Clinica Chimica Acta* **310** 193-197) compared the Shionogi IMRA BNP assay to the Biomedica EIA NT-proBNP assay with respect to the same population of 57 patients with stable chronic heart failure. In distinguishing subjects with decreased ventricular function from those with preserved

ventricular function, an AUC of 0.75 (± 0.06 s.e.) was obtained for the BNP assay, and an AUC of 0.67 (± 0.07 s.e.) was obtained for the Biomedica NT-proBNP assay. Following the method of Hanley and McNeil (Hanley JA and McNeil BJ (1983). "A method of comparing the areas under Receiver Operating Characteristic curves derived from the same cases." *Radiology* **148** 839-843), one finds that the Shionogi BNP assay has a significantly higher AUC than that of the Biomedica NT-proBNP assay (p = 0.009).

Luchner *et al.* (Luchner A, Hengstenberg C, Löwel H, Trawinski J, Baumann M, Riegger G, Schunkert H and Holmer S (2002). "N-Terminal Pro-Brain Natriuretic Peptide After Myocardial Infarction." *Hypertension* **39** 99-104) conducted a large clinical study involving 594 myocardial infarction subjects and 449 healthy controls, in order to determine the ability of the Roche EIA NT-proBNP assay to predict decreased ventricular function in these subjects. The authors quoted an AUC of 0.77 (± 0.057 s.e.) with respect to NT-proBNP in separating subjects with a left ventricular ejection fraction of less than 35% from those with a higher ejection fraction. This AUC is significantly lower than that

quoted above for the instantly disclosed NT-proBNP assay (p = 0.0001).

Thus, on the basis of quantifying the variously available assays for determining the presence of NT-proBNp based upon an area under the curve analysis, the instant assay would be expected to exhibit superior diagnostic performance.

All patents and publications mentioned in this specification are indicative of the levels of those skilled in the art to which the invention pertains. All patents and publications are herein incorporated by reference to the same extent as if each individual publication was specifically and individually indicated to be incorporated by reference.

It is to be understood that while a certain form of the invention is illustrated, it is not to be limited to the specific form or arrangement herein described and shown. It will be apparent to those skilled in the art that various changes may be made without departing from the scope of the invention and the invention is not to be considered limited to what is shown and described in the specification. One skilled in the art will readily appreciate that the present invention is well adapted to carry out the objectives and obtain the ends and

advantages mentioned, as well as those inherent therein. The embodiments, methods, procedures and techniques described herein are presently representative of the preferred embodiments, are intended to be exemplary and are not intended as limitations on the scope. Changes therein and other uses will occur to those skilled in the art which are encompassed within the spirit of the invention and are defined by the scope of the appended claims. Although the invention has been described in connection with specific preferred embodiments, it should be understood that the invention as claimed should not be unduly limited to such specific embodiments. Indeed, various modifications of the described modes for carrying out the invention which are obvious to those skilled in the art are intended to be within the scope of the following claims.

CLAIMS

What is Claimed is:

Claim 1. An enzyme linked immunosorbent assay (ELISA) process useful in diagnosing, stratifying, and predicting mortality rate in patients with congestive heart failure comprising:

obtaining isolated polyclonal antibodies specific for an amino acid sequence selected from the group consisting of amino acids 1-25 of Sequence ID No. 1, amino acids 26-51 of sequence ID No. 1, amino acids 52-76 of Sequence ID No. 1, and amino acids 77-108 of Sequence ID No. 1;

selecting a first polyclonal antibody from said group and attaching said polyclonal antibody to a solid support;

reacting a clinical sample suspected of containing immunogenic fragments of NT-proBNP with said isolated polyclonal antibody;

selecting a second polyclonal detector antibody selected as recognizing an amino acid sequence which is separate and distinct from the amino acid sequence recognized by said first polyclonal antibody;

effecting an immunoreaction; and

detecting said immunoreaction.

Claim 2. The assay of claim 1 wherein:

said first polyclonal antibody is selected as being specific to an amino acid sequence consisting of amino acids 26-51 of Sequence ID No. 1 and said second polyclonal antibody is selected as being specific to an amino acid sequence consisting of amino acids 1-25 of Sequence ID No. 1.

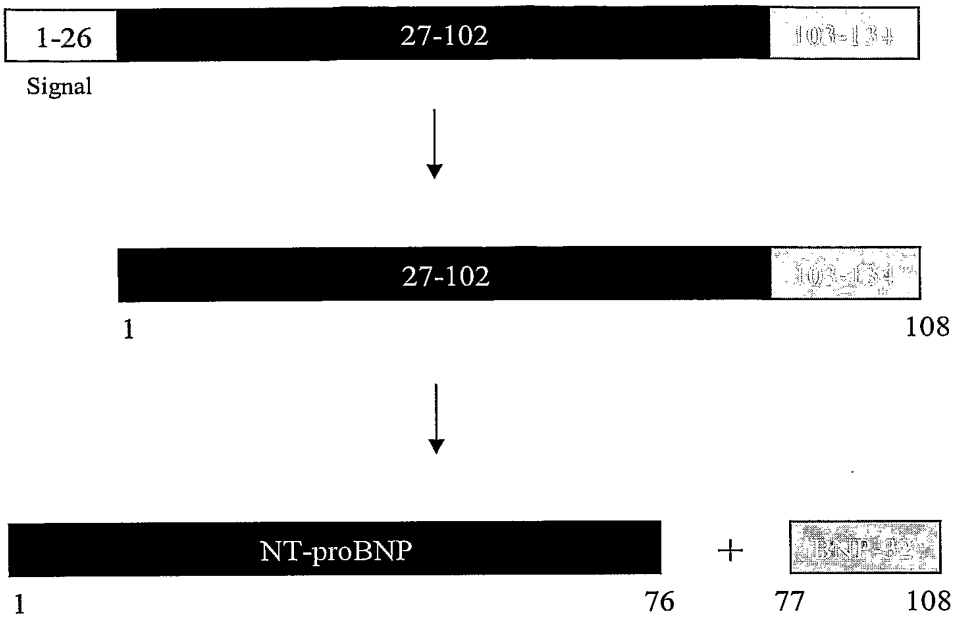
Claim 3. The assay of claim 1 wherein:

said first polyclonal antibody is selected as being specific to an amino acid sequence consisting of amino acids 1-25 of Sequence ID No. 1 and said second polyclonal antibody is selected as being specific to an amino acid sequence consisting of amino acids 26-51 of Sequence ID No. 1.

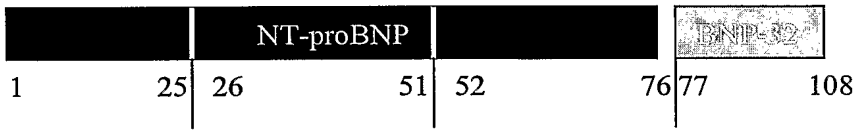
Claim 4. The assay of claim 1 wherein said detection is direct.

Claim 5. The assay of claim 1 wherein said detection is indirect.

FIGURE 1



Synthesized proBNP amino acid peptides (used for goat PAb affinity purification):



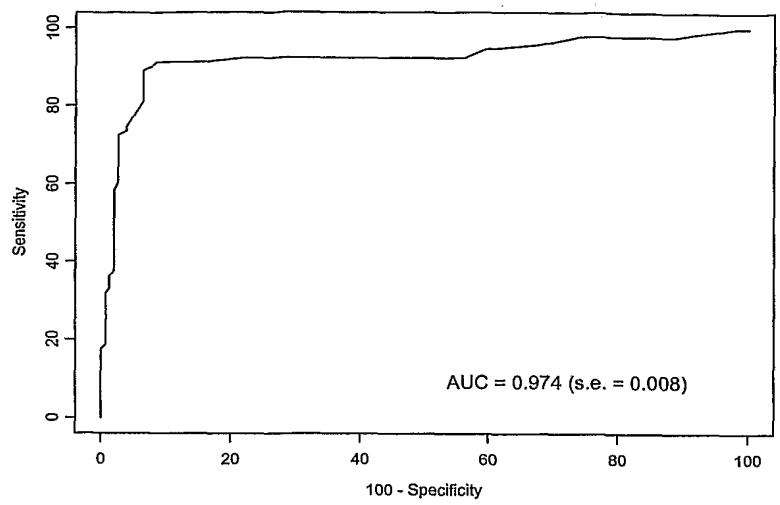


Figure 2: ROC curve for NT-proBNP (goat-goat assay).

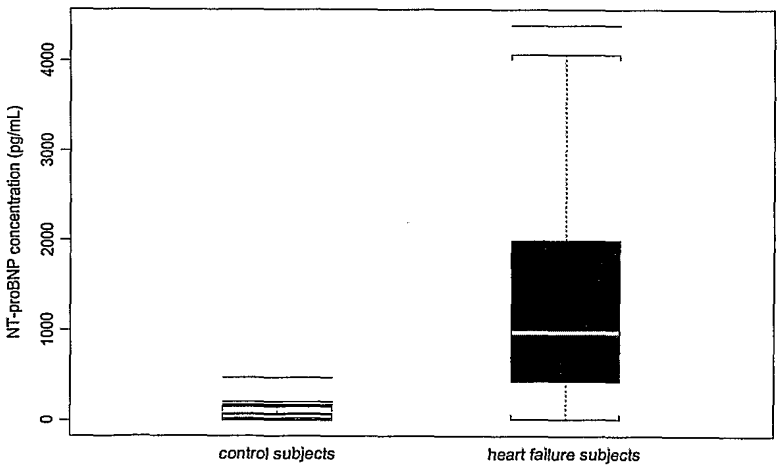


Figure 3: NT-proBNP (goat-goat assay) levels in control subjects and heart failure (NYHA Class III and IV) subjects.

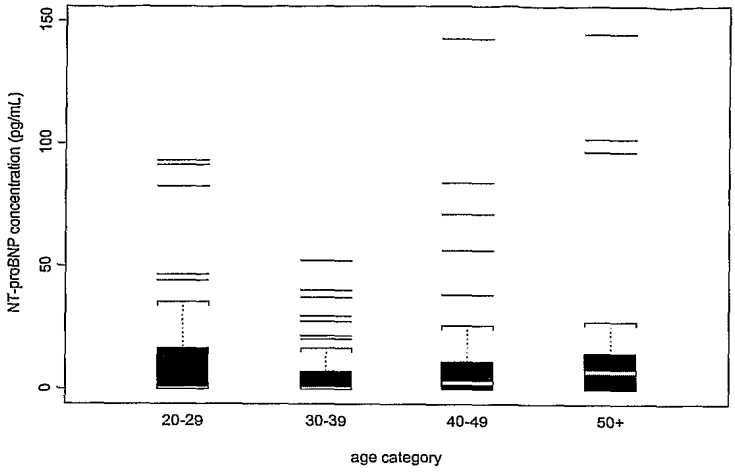
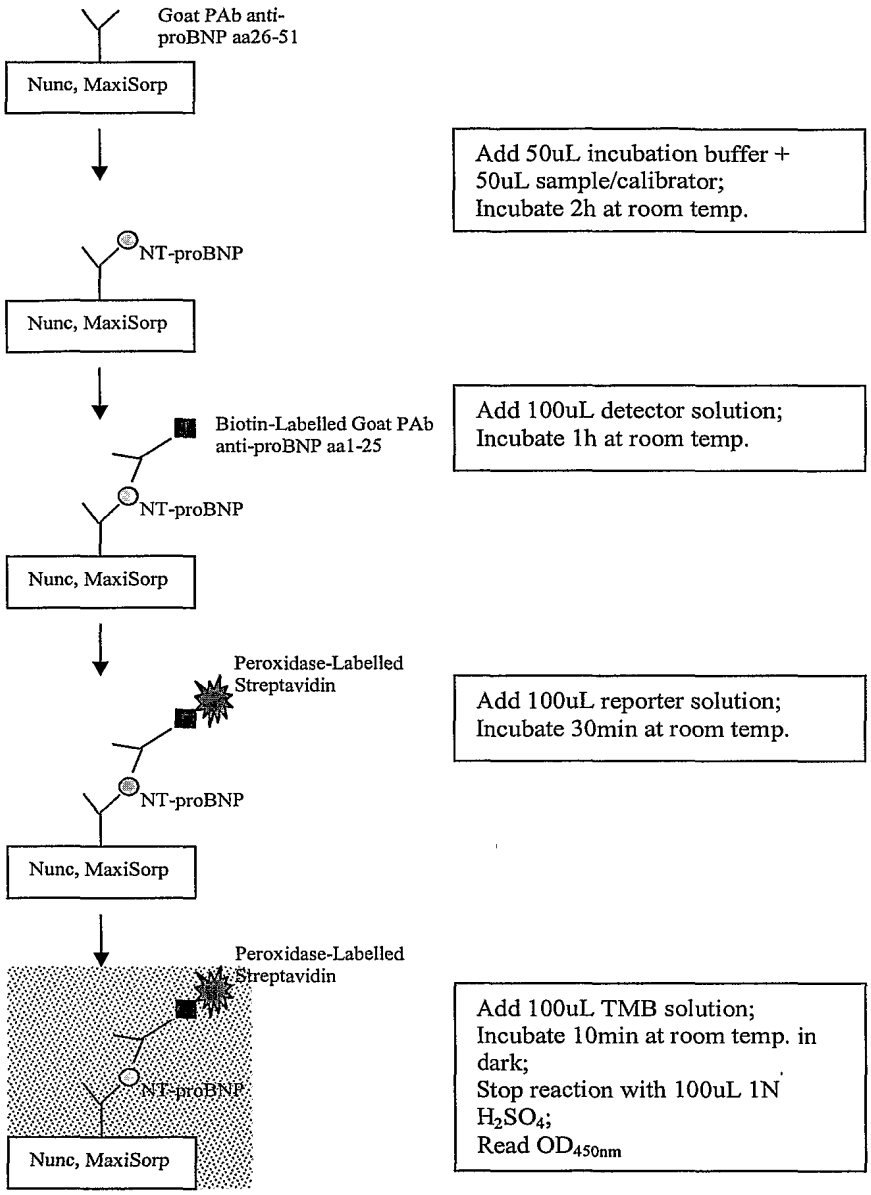


Figure 4: NT-proBNP levels in control subjects, stratified by age category.

FIGURE 5

NT-proBNP ASSAY CONFIGURATION AND ELISA PROCEDURE



SEQUENCE LISTING

<110> SYN X Pharma, Inc.

<120> Polyclonal-Polyclonal ELISA Assay for Detecting N-Terminus proBNP

<130> 08899184WO
<150> US 10/299,977
<151> 2002-11-18

<160> 1

<170> PatentIn version 3.1

<210> 1
<211> 108
<212> PRT
<213> Homo sapiens

<400> 1

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20 25 30

Val Glu Gln Thr Ser Leu Glu Pro Leu Gln Glu Ser Pro Arg Pro Thr
35 40 45

Gly Val Trp Lys Ser Arg Glu Val Ala Thr Glu Gly Ile Arg Gly His
50 55 60

Arg Lys Met Val Leu Tyr Thr Leu Arg Ala Pro Arg Ser Pro Lys Met
65 70 75 80

Val Gln Gly Ser Gly Cys Phe Gly Arg Lys Met Asp Arg Ile Ser Ser
85 90 95

Ser Ser Gly Leu Gly Cys Lys Val Leu Arg Arg His
100 105

INTERNATIONAL SEARCH REPORT

[redacted]national Application No
PCT/CA 03/01773

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01N33/68 G01N33/74

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, Sequence Search, BIOSIS, EMBASE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 00/35951 A (NG LEONG LOKE ; UNIV LEICESTER (GB)) 22 June 2000 (2000-06-22) cited in the application page 5, paragraph 4 - page 7, paragraph 4; claims; example 1	1-5
X	WO 00/45176 A (GALLUSSER ANDREAS ; KARL JOHANN (DE); LILL HELMUT (DE); STAHL PETER (D) 3 August 2000 (2000-08-03) cited in the application abstract page 5, paragraph 2 - page 7, paragraph 1; example 4	1-5
X	US 6 117 644 A (DEBOLD ADOLFO J) 12 September 2000 (2000-09-12) column 3, line 20 - line 38 column 9, line 25 - column 10, line 29	1-5

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 March 2004	16/04/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Luis Alves, D

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INTERNATIONAL SEARCH REPORT

[redacted]national Application No
PCT/CA 03/01773

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FISCHER YURIKO ET AL: "Evaluation of a new, rapid bedside test for quantitative determination of B-type natriuretic peptide" CLINICAL CHEMISTRY, vol. 47, no. 3, March 2001 (2001-03), pages 591-594, XP002274809 & ISSN: 0009-9147 the whole document	1-5
A	HUNT P J ET AL: "IMMUNOREACTIVE AMINO-TERMINAL PRO-BRAIN NATRIURETIC PEPTIDE (NT-PROBNP): A NEW MARKER OF CARDIAC IMPAIRMENT" CLINICAL ENDOCRINOLOGY, BLACKWELL SCIENTIFIC PUBLICATIONS, OXFORD, GB, vol. 47, 1997, pages 287-296, XP000913471 ISSN: 0300-0664 cited in the application abstract page 288, right-hand column, paragraph 1	1-5
A	CLERICO A ET AL: "Measurement of cardiac natriuretic hormones (atrial natriuretic peptide, brain natriuretic peptide, and related peptides) in clinical practice: The need for a new generation of immunoassay methods" CLINICAL CHEMISTRY, AMERICAN ASSOCIATION FOR CLINICAL CHEMISTRY. WINSTON, US, vol. 46, no. 10, October 2000 (2000-10), pages 1529-1534, XP002247285 ISSN: 0009-9147 page 1531, left-hand column, paragraph 2 - right-hand column, paragraph 7; table 1	1-5

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/CA 03/01773

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WO 0045176	A	03-08-2000	AU	758562 B2	27-03-2003
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			HU	0105195 A2	29-04-2002
			JP	2003508724 T	04-03-2003
			NO	20013698 A	28-09-2001
			NZ	512762 A	28-02-2003
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US 6117644	A	12-09-2000	NONE		